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ABSTRACT

First-, third- and fifth-grade children participated in a study of information seeking, using a "Twenty Questions" procedure with a hierarchical array of pictures. Economy of inquiry increased with grade but was unaffected by practice, replaying a game, or observing a model. Age differences in types of questions reflected differences in strategies. (Author)

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The Development of Information-seeking Strategies in Elementary School Children

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This study examines the development of information-seeking strategies in elementary school children, using a "Twenty Questions" paradigm. Among the purposes of the study were (1) to construct a detailed description of information-seeking strategies, based on precise definitions of the types of questions asked; (2) to attempt to induce children to improve their strategies by inviting them to reflect upon methods of inquiry (deficiencies in their own methods or efficiency in a model's method); (3) to examine differences in the use of positive and negative information.

Method

Subjects. The subjects were 90 middle-class children, 15 boys and 15 girls from each of three grades (first, third, and fifth) of a suburban elementary school. No IQ scores were available for first-graders. Categorized scores ("average," "high average," and "superior") were available for third- and fifth-graders. The distribution of children across categories was equivalent in third and fifth grade, with most falling in the high average range.

Procedure. The materials consisted of 16 simple line drawings of faces, each on a separate card, which could be arranged to

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form a four-level (2 x 2 x 2 x 2) hierarchy. (See Table 1). At each level the array can be divided into two categories of equal size, defined by at least one feature. The only feature unique to each card is its nonsense "name."

Each child was tested individually. After sorting the cards into all possible groupings, naming the features distinctive to each set, the children were told they were to play a game like "Twenty Questions;" the task was to discover which one of the 16 cards the experimenter had in mind, by asking questions answerable by "yes" or "no," using as few questions as possible. When the child understood the task, three trials were played, each with a different, pre-selected solution. The children were told that they could arrange the cards as they wished. In fact, two-thirds of the children at every grade arranged their cards randomly; most of the rest arranged them in pairs of twins.

Within each grade five boys and five girls were randomly assigned to one of three treatments: modeling, replay, or control. Control subjects simply proceeded to a fourth trial. Replay subjects first evaluated the questions they had asked on the third trial (e.g., LET'S SEE, YOU ASKED FIRST, IS IT RED? WAS THAT A GOOD QUESTION, DO YOU THINK? WAS THAT THE BEST QUESTION YOU COULD ASK?). Replay subjects then replayed the third trial, pretending they did not know the solution. For the modeling condition experimenter

and child reversed roles. The child chose a solution from an array of cards identical in structure to the array used previously but different in content: e.g., the 16 cards could be divided into two 8-member sets, but these sets were defined by size rather than gender. The model played the role of questioner, dividing the array in half with each question. Replay and modeling subjects then played a fourth game with the original array. The solutions were pre-selected to represent each of the four four-member classes, although I pretended to choose a solution at each trial.

Results

Economy of inquiry. Economy of inquiry was measured both by the number of questions asked (NQ) and by the size of the "chunk" or average expected information extracted with each question, a measure taken from Eimas (1970), based on the expected reduction of uncertainty in bits of information. Two analyses of variance were performed with NQ and chunk scores as dependent variables, and grade, treatment, and trials as independent variables. Since male and female scores were equivalent on both measures, they were pooled for these analyses. Significant main effects for grade were found for both NQ, F (2, 81) = 5.01, $p < .01$, and chunk scores, F (2, 81) = 17.10, $p < .001$. Neither analysis yielded significant interactions or significant main effects for treatment. Modeling and replay had no effect on economy of inquiry at any grade. There was no change in

chunk scores over trials, but NQ did vary with trial, F (3, 243) = 3.80, $p < .01$; a significant drop in NQ, consistent at every grade, occurred between Trials 2 and 3, t (89) = 2.08, $p < .05$. These findings reflect the children's tendency to use a non-replacement strategy, avoiding features present in earlier solutions. For example, children who consistently asked "color questions" tended to begin with an "unused" color more often than would be expected by chance on the third and fourth trials, χ^2 (1) = 3.37 and 3.86, respectively, $p < .10$.

A 2 x 3 analysis of variance with grade (third- vs. fifth) and IQ category as independent variables and chunk scores as the dependent variable showed a significant main effect for IQ, F (2, 54) = 17.33, $p < .001$, as well as grade.

Strategies of inquiry. Underlying the quantitative increase with age in efficiency were qualitative changes in strategies of inquiry. Questions were coded as to type, and strategies were defined in terms of the types of questions asked by each child on each trial. Three broad strategies were identified: instance-matching, category-scanning, and hierarchical narrowing. Instance-matchers test individual cards, while category-scanners test classes of cards. Instance-matchers deal in identity categories ("Is it X?"), while category-scanners deal in equivalence categories ("Is it a member of the class X?"). Instance-matchers attempt at each step

to identify the solution, while category-scanners begin by attempting to identify a range of potential solutions. Hierarchical narrowers use a half-split technique, organizing the entire array vertically as well as horizontally into symmetrical sub-sets nested within sets.

Instance-matching. In the pure form of instance-matching, "hypothesis-scanning," the child asks a series of "specific hypotheses" (questions referring to particular cards, e.g., "Is it DAX?") until s/he receives a yes. Hypothesis-scanning occurred only at Grade 1. Instance-matching occurred at Grade 3 only in the form of "disguised hypothesis-scanning." The essence of this strategy is as follows. Choose a card (a hypothesized solution) and test, at random, one of its features. If the feature is negative, repeat the procedure; if it is positive, test the card itself (by asking a specific hypothesis), or test another feature selected at random from the card. The strategy resembles hypothesis-scanning in that the focus at each step is on a particular card. The child does not appear to scan the array in search of categories; s/he seems to scan a card in search of features. A feature is selected not because it defines a class but because of its presence on a particular card. The strategy differs from hypothesis-scanning -- is disguised -- in that it involves feature-testing as well as direct testing of whole cards. In the clearest cases of disguised hypothesis-scanning,

the child asks a series of "pseudo-constraints," questions testing a feature present on only one card of the remaining array (e.g., "Does it begin with D?"), moving to a neighboring card with each "no." Given a "Yes," disguised hypothesis-scanners frequently asked "redundant questions," testing other features of the card: for example, after receiving a "yes" to "Does it begin with B?" one child stared at BIM's mouth while tracing it with a finger and saying, "Does it have a mouth?" Although instance-matching is clearly an extravagant strategy, it may involve considerable cognitive economy. Since instance-matchers nearly always moved systematically through rows or columns of their arrangement, no strain on memory occurred.

Instance-matching was much less frequent among the first-graders in this study than has been reported in earlier research. Specific hypotheses were less frequent and "constraint questions," questions referring to a feature contained by more than one remaining card, were more frequent than reported by Mosher and Hornsby (1966), for example. The difference is probably due to characteristics of the materials, the pictures used in this study being easier to categorize and harder to name, and perhaps to characteristics of the sample; Mosher and Hornsby's subjects were boys, and the mean percentage of specific hypotheses was higher for boys than for girls in the current study, $\underline{U} = 658.5$, $\underline{p} < .005$.

Category-scanning. In category-scanning the child asks a mixture of "symmetrical" and "asymmetrical" constraints, the former testing a feature common to half the remaining cards, the latter testing a feature common to more or less than half the remaining cards. The modal strategy of the first-graders was a form of category-scanning called color-scanning, in which the child tests one color category after another until receiving a "yes" (e.g., "Is it black? Is it blue?"). Color-scanning is also fairly extravagant, especially since color-scanners paid no attention to the size of the category defined by a particular color; they were as apt to begin with a two-member color category as with a four-member one. Nor did they appear to count the number of colors in the array; in almost every case in which the child had disconfirmed all but one color, s/he proceeded to test that color. Ault (1973) reports similar findings. In spite of these inefficiencies, color-scanning seemed in some ways an adaptive strategy. Although few children arranged their cards in color categories and almost none removed disconfirmed colors, no child ever re-tested a disconfirmed color. Color-scanners sometimes asked redundant questions, as in testing the one remaining color, but these questions were always consistent with information obtained; "violations," redundant questions testing features already logically eliminated, never occurred.

The modal strategy at Grade 3 was a form of category-scanning called "random category-scanning," in which the child tests a series

of categories selected on no discernible basis. That is, testing was not in terms of some consistent criterion like color, size of category (e.g., testing each two-member group, for example), or location (testing rows or columns of the array). For example, "Does it got stars/no. Is it blue/no. Is its hair curly/no..." These children did seem to be testing features defining categories, rather than features extracted from a particular card; for example, unlike disguised hypothesis-scanners, they did not stare at particular cards, and they asked no specific questions prior to locating a positive category. The major deficiency of random category-scanning is that it may burden the child with a complex inferential task. Random category-scanners cannot shed information as they go so easily as can the color-scanner, the hierarchical narrower, or even the systematic hypothesis-scanner. Consider, for example, the following mind-boggling sequence: "Is it curly/no. Does it have a tie/no. Does it have stars/no. Does it have a hat/no." In order to make the correct inference, that the solution has straight hair, the child must retain the first piece of information obtained, ignore the next two, transform the final piece into a positive statement (It doesn't have a hat, so it must be a girl) and then subtract the first from the last: "It's a girl, and it doesn't have curly hair, so it must have straight hair." Not surprisingly, this sort of reasoning appeared to be beyond the capacity of most

of the children. Children who became entangled in such sequences frequently resorted to redundant questions confirming the correct inference (in this case, "Does it have straight hair?") and sometimes simply sighed and started over. Fifth-graders might have been able to handle these complex inferential problems with more aplomb; in fact, because of their more systematic selection strategies, they rarely became enmeshed in such situations.

Hierarchical narrowing. Hierarchical narrowing was the modal strategy at Grade 5. In the pure form of this strategy the child asks a series of symmetrical constraints until two cards remain and then asks a specific hypothesis. Only eight fifth-graders used this strategy consistently on all four trials. Two less efficient variants of the strategy were common at Grade 5: after narrowing the domain to two cards, the child asks a pseudo-constraint or a redundant question confirming the remaining category. For example, after the sequence, "Is it a boy/yes; is it blue/no/ does it have dots/no," the child asks, "Does it begin with B?" or "Does it have stars?". In these cases it is as if the child has overgeneralized a rule recommending indirect testing to a situation in which direct testing would be more appropriate.

Postive and negative information. Children at every grade expressed a preference for positive information; yet, they used negative

information as efficiently as positive information. Differences in response to positive and negative outcomes consisted not in the number of errors but in the types of errors committed. At every grade children tended to "leap" to a specific hypothesis after receiving a "yes," even when information was logically insufficient to warrant a guess: e.g., "Is it green/yes. Is it BIM?" At every grade children tended to "linger" with a redundant question or, occasionally, a pseudo-constraint, after receiving a "no," even when information was logically sufficient to warrant a guess: e.g., "Is it black/yes. Does it have straight hair?" This behavior, with respect to both positive and negative information, is very similar to the behavior of adults, as reported by Bruner, Goodnow, and Austin (1956), Smedslund (1963), Wason (1968), and others.

Modeling and replay. The behavior of the children in the modeling and replay conditions suggests some reasons for the failure of these treatments to promote economy of inquiry. Few children in the replay condition were able to articulate flaws in their own performance on Trial 3, although there was an interesting shift with age in the criteria used for evaluation. First-graders evaluated questions in terms of their actual outcomes; thus, "Is it black" was a good question, "'cause DAX (the solution) is black." Fifth-graders referred to possible outcomes; "Is it a boy?" was a good question, because "it divides it in half." Third-graders vacillated between the two criteria.

The children performed no better in replaying the third trial than when playing it for the first time. The children did try to pretend that they did not know the solution; they did not plunge right to the solution, as shown by the fact that NQ was no lower during replay than on the third trial. They did show a tendency toward fixation on the correct card, however; during replay 37% asked nothing but questions receiving a "yes," as compared with 7% on Trial 3, χ^2 (1) = 5.81, $p < .02$. In some cases the child appeared to be glued to the correct card, reeling off one redundant question after another. Some children, apparently anxious to avoid the appearance of cheating, showed a tendency to avoid testing the solution card -- testing all five "wrong" colors, for example, before testing the right one, or refusing to venture a specific hypothesis after narrowing the domain to two cards (saying to the experimenter, "You pick one."). Although it had been hoped that the replay procedure would induce decentering, giving the child an opportunity to stand back and reflect upon his strategy in a situation in which he need not worry about "getting the answer," in fact, the procedure may have required a capacity to decenter that was beyond the reach of most of the children.

Observation of the model produced no measurable improvement in performance except for an increase in constraint questions, largely at the expense of specific hypotheses, consistent at all

grades, but significant only at Grade 1, t (9) = 2.58, $p < .05$. I suspect that this change was more figurative than operative, more linguistic than cognitive. The children appeared to copy the model's behavior; they did not seem to induce the rules generating that behavior. The model used language emphasizing the categorical nature of the array (e.g., "Is it one of the big ones?" rather than "Is it big?"). Many children switched to this sort of language on the fourth trial. Specific hypotheses cannot be asked in this form, and hypothesis-scanners did exercise more constraint on the fourth trial, but many other children switched the form but not the substance of their questions. Distinctions between redundant and informative questions and between asymmetrical and symmetrical constraints are not linguistically marked, and there was no change in the frequency of these sorts of questions after modeling. Children imitated other aspects of the model's behavior on Trial 4, but, again, without improving their performance. The model had arranged the cards in hierarchical order. Some children, who had ordered their cards randomly before modeling, announced that they were "doing the same thing" and proceeded to construct idiosyncratic arrangements (e.g., alternating boy and girl cards). The model had eliminated irrelevant cards after each outcome. No child had done this on the first three trials; some did on Trial 4, but without good effect. One color-scanner, for example, removed each card after it was in-

firmed until faced with only two black cards; he asked, "Is it black?" In general, like the children in the replay condition evaluating their own questions, the children appeared to focus on the immediate outcome of the model's questions, rather than on the quality of the questions: they were pleased when the model received a "no" and dismayed when she received a "yes."

Conclusions

In attempting to understand the development of information-seeking it is important to examine changes not only in overall efficiency but in the types of questions asked. Development does not take the form of random elimination of less economical questions in favor of more economical ones. In this study, for example, redundant questions -- the least economical of questions -- were most frequent at Grade 3. It is important, too, to examine each question in the context of the child's overall search strategy, because the meaning of a question varies, depending upon the situation in which it is asked. For example, in this study redundant "reaffirmations" declined sharply between Grades 3 and 5. Reaffirmations are questions referring to a card or feature already shown, by positive feedback, to be correct (e.g., "Does it have a hat/yes. Is it a boy?"). Redundant "confirmations" were as frequent at Grade 5 as at Grade 3. Confirmations refer to a card or feature already shown, by negative feedback, to be correct (e.g., "Is it a boy/no. Is it a girl?"). These two sorts of questions appear to make quite different cognitive demands. Another example: "pseudo-constraints"

have been treated as developmentally transitional between hypothesis-scanning and constraint-seeking (Ault, 1977; Mosher & Hornsby, 1966), representing the shadow but not the substance of categorical testing. In this study the first- and third-graders' pseudo-constraints did seem to take this form; they were asked as part of a strategy of disguised hypothesis-testing when constraints were appropriate. But the fifth-graders' pseudo-constraints were asked, usually, after reducing the domain to two cards, when a specific hypothesis was appropriate. Thus, for older children pseudo-constraints are overly indirect, while for younger children they are overly direct.

Much of our understanding of the development of information-seeking is still in the realm of speculation. In the time remaining, let me offer just one speculation. It is that serendipity plays a role in this development. Serendipity is the faculty of finding valuable things not sought for. I think that the child's grasp often exceeds his reach in information-seeking. That is, his selection of information often seems less sophisticated than his use of information. In early category-scanning, as well as in disguised hypothesis-scanning, the children often make it clear that their aim is to test an instance, rather than a category. For example, one child began by saying, "Let's see. I'm pretty sure it's BIM. What'll I ask? Oh. Is it green?" But more often than not the children applied the information they obtained to an entire category of cards; given a "yes," the child surveyed the array for other instances of that class (in this case, other green cards), and

given a "no," eliminated the entire class from consideration. Hindsight may then lead to foresight; having collected usable categorical information, the child may begin deliberately to select such information. Similarly, evidence not presented here suggests that when children first mount a hierarchical strategy they are not aiming at symmetrical cuts; they are simply testing the largest available categories, those most likely to yield a "yes." But the strategy yields not only comforting "yesses" but potentially valuable "no's." The child may then come to see that symmetrical constraints render positive and negative outcomes equally useful, and may begin to use symmetry, rather than size, as a criterion for selection.